REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.2331(UIF)
VOLUME - 7 | ISSUE - 5 | FEBRUARY - 2018

CREEP EXAMINATION OF A TRANSVERSELY ISOTROPIC

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ABSTRACT:

In this paper, the creep behavior of a transversely isotropic rotating FGM disc is investigated. The SiCp reinforcement content in the matrix of pure aluminum is non-linearly decreasing along the radius. The thickness profile of the rotating disc is linearly decreasing along the radius. It is observed that the radial and tangential stresses changes slightly in FGM disc with α = 1.25 as compare isotropic FGM disc (α = 1).

KEYWORDS: *FGM, Creep, Modeling, Anisotropy, Variable thickness*

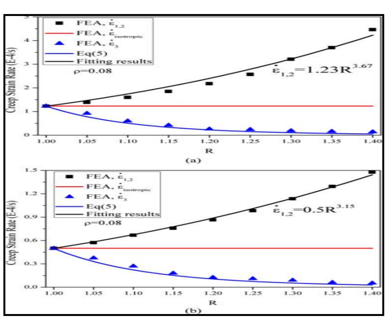
INTRODUCTION

Rotating disc has been the subject of intensive investigations because of its use in different engineering applications (Gupta *et al*., 2005; Garg et al., 2012). Analysis of stresses and strains has been receiving widespread attention due to its wide applications in engineering devices like turbine rotors, flywheels, pumps, disc brakes, etc. (Hojjati and Hassani, 2008, Callioglu *et al*., 2011).

Bhatnagar et al (1986) performed crawl examination of an orthotropic pivoting plate having distinctive thickness profiles by utilizing Norton's energy law. Tutuncu (1995) observed the effect of anisotropy on the stresses and deformations in an orthotropic rotating circular plates.

Callioglu (2004) investigated stress analysis on a glass-fiber/epoxy orthotropic rotating hollow discs. The temperature from inner surface to outer surface along the radial sections. It is observed investigated the effect of anisotropy on elastic-plastic stresses in a rotating annular disc. To incorporate the effect of anisotropy on the plastic flow, Hill's quadratic orthotropic yield criterion and its associated flow rule were used. The study evaluates the influence of introducing various kinds of anisotropy on stress distribution in a rotating disc.

Rotating disc is a widely used component in engineering and structural applications, involving severe thermo-mechanical loadings where creep becomes significant. Under severe thermomechanical loadings, the conventional materials may not survive alone.



Singh and Ray [4] broke down consistent state sneak in a pivoting isotropic FGM circle of steady thickness by utilizing Norton's energy law.. The study reveals to a similar disc made of Non-FGM composite. Gupta et al [3] extended the work of Singh and Ray [4] to investigate the steady state creep in a constant thickness rotating FGM disc operating under a radial thermal gradient by using sherby's creep law. It is watched that the strain rates in composite plate working under an outspread warm angle are lower than those saw in a comparative composite circle, however subjected to a steady normal temperature, which is the normal of forced warm inclination.

Zenkour [5] presented a solution procedure to estimate the distribution of stresses in rotating functionally graded disc of constant thickness. The study indicates that the stresses and deformations in the disc are lower when the material of the disc is tailored in such a way that the elastic modulus and density are more near the inner radius than those at the outer radius.

Dwivedi *et al* [6] studied the effect of varying disc thickness profile on creep behavior of rotating FGM disc with linearly varying thickness. The study shows that with the increase in disc thickness gradient, the radial, tangential and effective stresses decrease over the entire disc radius. The strain rates in the disc also reduce significantly with the increase in disc thickness gradient.

Though, some of the workers investigated creep in variable thickness FGM disc but they assumed linear distribution of reinforcement in the disc. Therefore, it has been decided to investigate the creep behavior of variable thickness FGM disc with different profiles of distribution of reinforcement.

It is uncovered by a few agents that sneak strains in factor thickness pivoting circle are much lower as think about consistent thickness plate. The writing counseled so far uncovers that the investigation relating to crawl conduct of anisotropic FGM plate isn't accessible. The present study aims to investigate the effect of anisotropy on creep behavior of a rotating FGM disc.

DISC PROFILE AND DISTRIBUTION OF REINFORCEMENT

Consider a rotating FGM disc having variable thickness and made of anisotropic Al-SiCp. The inner and outer radii of the disc are taken respectively as '*a*' and '*b*' and the rpm of the disc is assumed to be 15000. The thickness of the circle is accepted to shift straightly from the inward to external span as indicated by the accompanying condition,

h(r) = hb + 2k(b-r) (1)

Where, ha (= 43.22 mm) and h b (=13.97 mm) are circle thickness at the internal and external radii and k is a steady.

The content of SiCp content in the FGM disc is assumed to decrease according to the following equation,

$$V(r) = V_{\max} - \frac{(r-a)^2}{(b-a)^2}(V_{\max} - V_{\min}) \quad (2)$$

where *Vmax* and *Vmin* are respectively the maximum (at inner radius) and the minimum (at outer radius) SiCp content in the FGM disc.

The average SiCp content in the FGM disc can be expressed by,

$$V_{av} = \frac{\int_a^b 2\pi r h(r) V(r) dr}{[\pi(b^2 - a^2)t]} \quad (3)$$

Substituting *h*(*r*) and *V*(*r*) respectively from Eqs. (1) and (2) into Eq. (3), we get,

$$V_{\min} = \frac{30V_{av}(b+a)t - V_{\max}[h_b(8b+7a) + h_a(7b+18a)]}{[h_b(12b+3a) + h_a(3b+2a)]} \quad (4)$$

Since density of the disc is a function of SiCp content, therefore, it will also vary along the radial direction. The density, *p(r)*, of the FGM disc at any radius *r* may be estimated from the rule of mixture,

$$\rho(r) = \rho_m + \frac{(\rho_d - \rho_m)V(r)}{100} = A_\rho - B_\rho(r-a)^2 \quad (5)$$

Creep Law

The steady state creep behavior of the composite disc is described by threshold stress (σ_o) based law (Ma and Tjong, 2001) given by,

$$\dot{\bar{\varepsilon}} = \left[M(r)\{\bar{\sigma} - \sigma_0(r)\}\right]^n \quad (6)$$

where $M(r)$ and $\sigma_o(r)$ are the creep parameters. The value of true stress exponent (n) in Eq. (6) is kept equal to 5.The creep parameters $M(r)$ and $\sigma_o(r)$ are given by (Deepak *et al.,* 2010),

$$M(r) = 0.0288 - \frac{0.0088}{P} - \frac{14.0267}{T} + \frac{0.0322}{V(r)} \quad (7)$$

$$\sigma_0(r) - -0.084P - 0.023T + 1.185\,V(r) + 22.207 \quad (8)$$

ANALYSIS OF CREEP IN FGM DISC

The analysis carried out in this study is based on the following assumptions:
1. The disc is made of transversely isotropic material, *i.e.*, the properties of the disc remain same in the radial (r) and axial (z) directions but are different in tangential (θ) direction.
2. Elastic deformations in the disc are small and hence neglected as compared to creep deformations.
3. The axial stress (σ_z) in the disc remains zero.
4.Material of the disc is locally isotropic.
5.Elastic misshapenings in the plate are little and thus dismissed when contrasted with crawl distortions.

The effective stress (σ) in a transversely isotropic rotating disc under biaxial state of stress (*i.e.* σz =0) is given by Hill's yield criterion (Dieter, 1988).

RESULTS AND DISCUSSIONS

A computer code based on the analysis given in last section has been developed to obtain the distribution with anisotropic properties. The effect of variation in anisotropy constant (α) has been studied on the creep stresses and strain rates in the disc. The value of α greater than unity means the weakening of the disc in the tangential direction as compare to radial and axial directions. But the value of α =1 implies that the disc material is isotropic.

A computer code based on the analysis given in last section has been developed to obtain the distribution of stresses and strain rates in the FGM disc with different reinforcement gradation index. For comparison, the results have also been obtained for a FGM disc having uniform distribution of SiCp along the radius.

CIRCULATION OF STRESSES AND STRAIN RATES

The impact of anisotropy on the crawl conduct of a variable thickness FGM circle is appeared in Figs. 1(a) and 1(b). The results computed for FGM disc with α =1.25 are compared with the results of isotropic FGM disc (α =1). The radial stress in the disc decreases with the increase in extent of anisotropy from 1 to 1.25. The change observed in radial stress is significant in the middle region of the disc but negligible near the inner and outer radii. The effect of varying α on tangential stress is shown in Figure 4(b). As compared to isotropic FGM disc (α =1), the tangential stress increases near the inner radius but decreases towards the outer radius for FGM disc having α<1. The impact of α on digressive pressure is simply inverse when it's esteem is more noteworthy than 1 (i.e. α >1). The impact of shifting α on distracting pressure is more close to the inward span than that saw close to the external range.

Not surprisingly the strain rates, spiral and in addition digressive, diminish essentially finished the whole sweep, with the expansion in α from 0.5 to 1.0 (Figures 6a-6b). The change saw in strain rates is more close to the internal sweep than that saw towards the external span. The FGM circle having α = 1.5 displays the most reduced strain rates when contrasted with some other FGM plate. In this way, it is obvious that by utilizing FGM circle with higher quality along the spiral and hub headings contrasted with unrelated course, i.e. ⍰ > 1, the compelling anxiety rates in the circle are altogether decreased.

The decrease observed is more near the inner radius than that noticed towards the outer radius. It is also evident from Figs. that with increasing gradation index (*m*) of the disc, the distribution of strain rates in the disc becomes relatively more uniform. Therefore, the FGM disc having respectively higher gradation index (*m*) will have lesser chances of distortion.

CONCLUSIONS

With the increase in reinforcement gradation index, the radial stress in the FGM disc increases throughput. The decrease observed in tangential stress, towards the outer radius, is slightly higher than the increase noticed near the inner radius. It is also observed that with the increase in reinforcement gradation index, the radial as well as tangential strain rates in the disc decreases throughout. The decrease observed towards the inner radius is slightly higher than that observed towards the outer radius.

The study carried out has led to the following conclusions:

1. The spiral and additionally unrelated worries in FGM plate are influenced within the sight of anisotropy. In anisotropic FGM circle having α >1, the spiral pressure diminishes a little finished the whole plate while the distracting pressure diminishes somewhat close to the internal sweep however increments marginally towards the external span, when contrasted and isotropic FGM plate (α =1).
2. The radial and tangential strain rates in the FGM disc reduce significantly with the increase in extent of anisotropy from 1.0 to 1.25.

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